UPGRADING OF THE POWER SUPPLY FOR MAGNET U70 SYNCHROTRON

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Abstract

At the accelerator complex U70 NRC "KI" - IHEP, there is work to expand the range of the working beam energy for physical experiments. We are talking about medium energies for protons (350 ÷ 1300) MeV/u, as well as carbon ions (250 ÷ 455) MeV/u. The presence of extracted beams of medium energies opens up new possibilities for proton radiography, radiobiological studies, etc.

Analysis of the options for obtaining beams of medium energies in the accelerator complex has shown that the creation of a deceleration regime for particles in the U70 is optimal. Firstly, we do not change the standard setting of the injection complex with the beam transport channels in the cascade of the LU30–U1.5, I100–U1.5 accelerators, and secondly for this regime we have a well-developed arsenal of technical means in the U70. The missing link is a regulated power supply for the U70 electromagnet with the following characteristics: power ≈ 30 kW; the maximum current is 150 A with accuracy not worse than $\pm 1 \cdot 10^{-4}$; the maximum voltage on the plugs ±450 V with accuracy not worse than $\pm 1 \cdot 10^{-3}$.

The ring electromagnet (REM) U70 is designed with combined functions that ensure the circulation of particles in the equilibrium orbit and simultaneously their focusing. The main characteristics and design features of the synchrotron electromagnet IHEP were published in [1]. REM in its simplest form can be represented as a C-shaped transformer with an air gap. The primary winding is the main winding of the REM, which creates a leading magnetic field, the secondary windings are the corrective windings of the magnetic field U70.

The report describes the upgrade of the source with pulse-width modulation (PWM) voltage for our purpose.

The existing commercial source was not satisfied due to electromagnetic incompatibility due to the transformer coupling of the windings creating a magnetic field in the U70. The problem was to suppress 100% of the output voltage ripple by approximately 1000 times (- 60 dB).

RESEARCH SOURCE WITH PWM + REM

Test №1

The power supply was connected to the U70 electromagnet. To obtain the energies indicated above, the law of current was established to form the magnetic cycle of slowing down the light ion beam (130 ÷ 80) A. The output characteristics of the current and voltage were measured. The following instruments were used: oscilloscope Tektronix 4000 series; Differential Probe DP-25, calibration ± 1 V ⇒ ± 200 V; current sensor LEM IT 200-S, calibration ± 10 V ⇒ ± 164 A. The signals were taken from the output of the power supply busbar. In Fig. 1 the results of tests a commercial power supply are given.

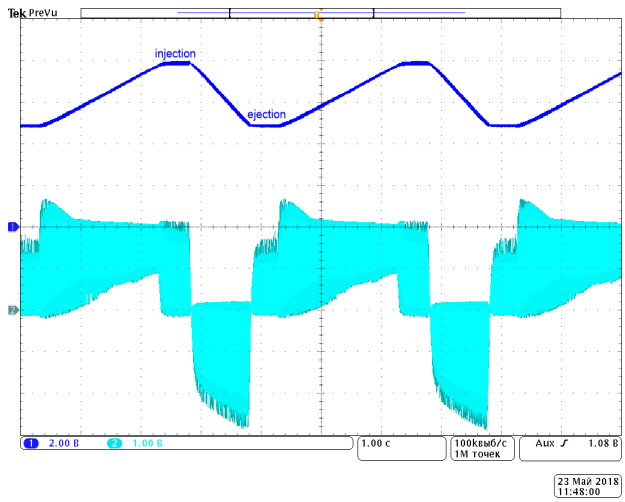

Figure 1: Current law, for the formation of the magnetic cycle of slowing down the beam of light ions in the U70, (130 ÷ 80) A. The upper trace – current, the lower trace – voltage with 100% ripple (Peak to peak) – 1000 V, frequency PWM ~20 kHz.

Low-pass filter (LPF)

To suppress pulsations, the required type of LPF was chosen. The calculation of filter elements is carried out in PSpice codes for the equivalent circuit shown in Fig. 2. An iterative, numerical method with optimization of the element values according to the established criteria was used [2-5]. The cutoff frequency of the LPF is 300 Hz. The suppression of pulsations at the fundamental generation frequency of 20 kHz reaches - 60 dB (refer Fig. 3).

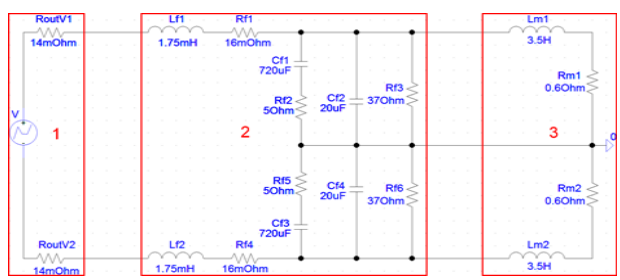

Figure 2: Equivalent simulation scheme. Blocks highlight the main parts: 1 – commercial power supply, 2 – LPF, 3 – load (REM U70).

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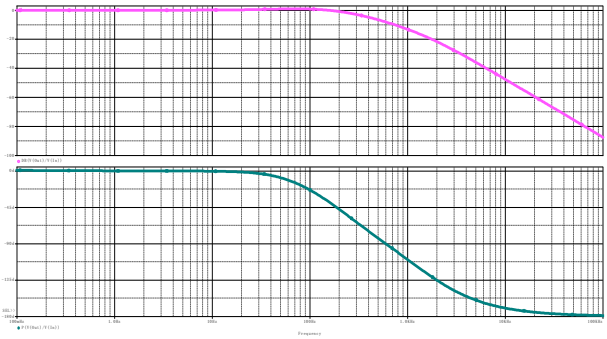

Figure 3: The Bode diagram of a LPF. Graphs from top to bottom: amplitude-frequency and phase-frequency characteristics.

RESEARCH SOURCE WITH PWM + LPF + REM

Test №2

According to the simulated scheme, Fig. 2, the LPF was built and connected (refer Fig. 5). Test № 1 was repeated, the signals were taken from the output terminals of the LPF. In Fig. 4 the result of operation of the upgraded power supply is shown.

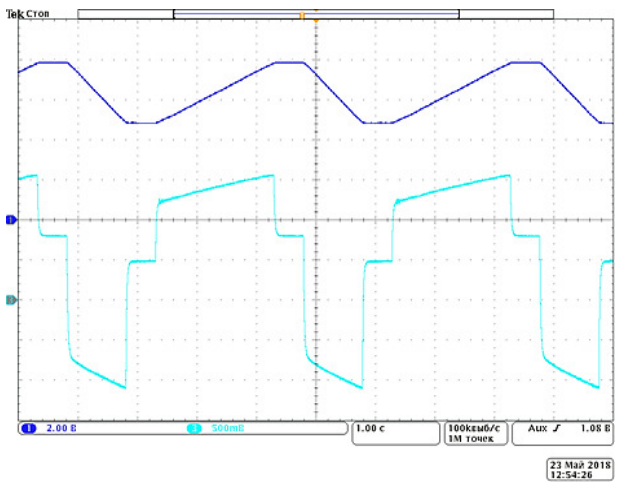

Figure 4: Current law, for the formation of the magnetic cycle of slowing down the beam of light ions in the U70, (130 ÷ 80) A. The upper trace – current, the lower trace – voltage in which pulsations have decreased ~ 1000 times.

Figure 5: Stand (without walls) of the LPF.

CONCLUSION

As a result of the upgrade of a typical commercial power supply with pulse-width modulation, the source became usable for deceleration the beam of light ions in the U70.

We managed to suppress electromagnetic radiation in the REM U70 and thereby eliminate the effect of electromagnetic incompatibility with surrounding equipment.

REFERENCES

[1] E.G. Komar, et al. The main characteristics and features of the design electromagnet synchrotron IHEP, Proceedings of the All-Union Conference on Accelerators of Charged Particles, Moscow, October 9-16, 1968, vol. 1, p. 164-168, VINITI, Moscow, 1970.

[2] U.M. Sibert. Chains, signals, systems: In 2 parts the translation from English — M.: World, 1988.

[3] G. Hanzel. Handbook on the calculation of filters. Moscow, "Soviet Radio", 1974.

[4] A. Ango. Mathematics for electro and radio engineers. M., "Science", 1965.

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